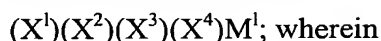


CLAIMS

We Claim:

- 5 1. A compound having the following formula:

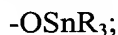


M^1 is selected from titanium, zirconium, or hafnium;

(X^1) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;

- 10 each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X^1) is independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

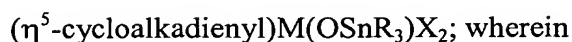
(X^2) is selected from a stanoxo group with the following formula:



- 20 wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

- 25 (X^3) and (X^4) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 30 20 carbon atoms; or a halide.

2. The compound of Claim 1, wherein the compound has the following general formula:



5 cycloalkadienyl is selected from cyclopentadienyl, indenyl, fluorenyl, or substituted analogs thereof;

M is selected from Ti, Zr, or Hf;

R is independently selected from substituted or non-substituted alkyl, cycloalkyl, aryl, aralkyl, alkoxide, or aryloxy, any one of which having from 1 to
10 about 20 carbon atoms; F; Cl; Br; or I; and

X is independently selected from F; Cl; Br; I; or a substituted or non-substituted alkyl, cycloalkyl, aryl, aralkyl, alkoxide, or aryloxy, any one of which having from 1 to about 20 carbon atoms.

15 3. The compound of Claim 1, wherein the compound is selected from:

(η^5 -cyclopentadienyl)titanium(triphenylstannoxy)dichloride;

(η^5 -cyclopentadienyl)zirconium(triphenylstannoxy)dichloride;

(η^5 -cyclopentadienyl)titanium(trimethylstannoxy)dichloride;

(η^5 -cyclopentadienyl)zirconium(triethylstannoxy)dichloride;

20 (η^5 -cyclopentadienyl)hafnium(triphenylstannoxy)dichloride;

(η^5 -cyclopentadienyl)titanium(tri-n-butylstannoxy)dichloride;

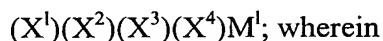
(η^5 -cyclopentadienyl)titanium(triphenylstannoxy)dibromide;

(η^5 -pentamethylcyclopentadienyl)titanium(triphenylstannoxy)dibromide;

or

25 (η^5 -cyclopentadienyl)titanium(tributylstannoxy)dibromide.

4. A composition of matter comprising a half-sandwich metallocene compound with the following formula:



30 M^1 is selected from titanium, zirconium, or hafnium;

(X¹) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;

each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X¹) is independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

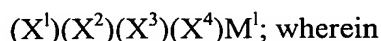
(X²) is selected from a stannoxy group with the following formula:



wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

(X³) and (X⁴) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; or a halide.

5. A catalyst composition comprising a half-sandwich metallocene compound with the following formula:



M¹ is selected from titanium, zirconium, or hafnium;

(X¹) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;

each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X^1) is independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

(X^2) is selected from a stannoxy group with the following formula:
-OSnR₃;

wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

(X^3) and (X^4) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; or a halide.

6. A catalyst composition comprising:
- a) a half-sandwich metallocene compound with the following formula:
 $(X^1)(X^2)(X^3)(X^4)M^1$; wherein
 M^1 is selected from titanium, zirconium, or hafnium;
(X^1) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;
- each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X^1) is independently selected from an aliphatic group, an

aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

(X²) is selected from a stannoxy group with the following formula:



wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

(X³) and (X⁴) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; or a halide; and

b) a chemically-treated solid oxide comprising a solid oxide treated with an electron-withdrawing anion;

wherein the solid oxide is selected from silica, alumina, silica-alumina, aluminum phosphate, heteropolytungstates, titania, zirconia, magnesia, boria, zinc oxide, mixed oxides thereof, or mixtures thereof; and

the electron-withdrawing anion is selected from fluoride, chloride, bromide, phosphate, triflate, bisulfate, sulfate, or any combination thereof.

7. The catalyst composition of Claim 6, wherein the chemically-treated solid oxide further comprises a metal or metal ion.

8. The catalyst composition of Claim 6, wherein the chemically-treated solid oxide further comprises a metal or metal ion, and wherein the chemically-treated solid oxide is selected from zinc-impregnated chlorided alumina, zinc-impregnated fluorided alumina, zinc-impregnated chlorided silica-alumina, zinc-impregnated fluorided silica-alumina, zinc-impregnated sulfated alumina, or any combination thereof.
9. The catalyst composition of Claim 6, wherein the chemically-treated solid oxide further comprises a metal or metal ion selected from zinc, nickel, vanadium, silver, copper, gallium, tin, tungsten, molybdenum, or any combination thereof.
10. The catalyst composition of Claim 6, wherein the chemically-treated solid oxide comprises fluorided silica alumina which comprises from about 5% to about 95% by weight alumina and from about 2% to about 50% by weight fluoride ion, based on the weight of the fluorided silica-alumina after drying but before calcining.
11. The catalyst composition of Claim 6, wherein the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, bromided alumina, fluorided silica-alumina, chlorided silica-alumina, sulfated alumina, sulfated silica-alumina, or a combination thereof.
12. A catalyst composition comprising:
- a) a half-sandwich metallocene compound with the following formula:
- $$(X^1)(X^2)(X^3)(X^4)M^1; \text{ wherein}$$
- M^1 is selected from titanium, zirconium, or hafnium;
- (X^1) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;
- each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X^1) is independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an

oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

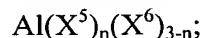
(X²) is selected from a stannoxy group with the following formula:



wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

(X³) and (X⁴) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; or a halide; and

b) an organoaluminum compound with the following formula:

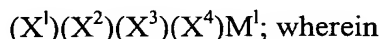


wherein (X⁵) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X⁶) is selected from alkoxide or aryloxy, any one of which having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

25

13. A catalyst composition comprising:

a) a half-sandwich metallocene compound with the following formula:



M¹ is selected from titanium, zirconium, or hafnium;

(X¹) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;

each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X^1) is independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

(X^2) is selected from a stannoxy group with the following formula:
-OSnR₃;

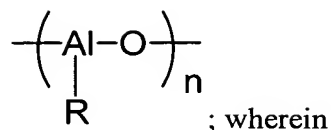
wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

(X^3) and (X^4) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; or a halide; and

b) an activator selected from an aluminoxane, an organoboron compound, an ionizing ionic compound, a clay material, a chemically-treated solid oxide combined with an organoaluminum compound, or any combination thereof.

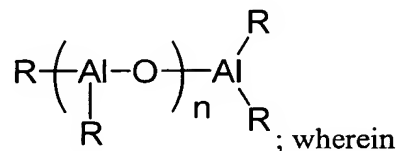
14. The catalyst composition of Claim 13, wherein the activator comprises an aluminoxane comprising:

a cyclic aluminoxane having the formula:



R is a linear or branched alkyl having from 1 to 10 carbon atoms, and n is an integer from 3 to about 10;

a linear aluminoxane having the formula:



5

R is a linear or branched alkyl having from 1 to 10 carbon atoms, and n is an integer from 1 to about 50;

a cage aluminoxane having the formula $\text{R}^{\text{t}}_{5m+\alpha} \text{R}^{\text{b}}_{m-\alpha} \text{Al}_{4m} \text{O}_{3m}$, wherein m is 3 or 4 and α is $= n_{\text{Al}(3)} - n_{\text{O}(2)} + n_{\text{O}(4)}$; wherein $n_{\text{Al}(3)}$ is the number of three coordinate aluminum atoms, $n_{\text{O}(2)}$ is the number of two coordinate oxygen atoms, $n_{\text{O}(4)}$ is the number of 4 coordinate oxygen atoms, R^{t} represents a terminal alkyl group, and R^{b} represents a bridging alkyl group; wherein R is a linear or branched alkyl having from 1 to 10 carbon atoms; or
any combination thereof.

15

15. The catalyst composition of Claim 14, wherein the molar ratio of the aluminum in the aluminoxane to the half-sandwich metallocene in the composition is from about 1:1 to about 100,000:1.

20 16. The catalyst composition of Claim 13, wherein the activator comprises an aluminoxane selected from methylaluminoxane, ethylaluminoxane, n-propylaluminoxane, iso-propylaluminoxane, n-butylaluminoxane, t-butylaluminoxane, sec-butylaluminoxane, iso-butylaluminoxane, 1-pentylaluminoxane, 2-pentylaluminoxane, 3-pentylaluminoxane, iso-pentylaluminoxane,
25 neopentylaluminoxane, or any combination thereof.

17. The catalyst composition of Claim 13, wherein the activator comprises an organoboron compound selected from tris(pentafluorophenyl)boron, tris[3,5-bis(trifluoromethyl)phenyl]boron, or a combination thereof.
- 5 18. The catalyst composition of Claim 17, wherein the molar ratio of the organoboron compound to the half-sandwich metallocene in the composition is from about 0.5:1 to about 10:1.
- 10 19. The catalyst composition of Claim 13, wherein the activator comprises an ionizing ionic compound selected from tri(n-butyl)ammonium tetrakis(p-tolyl)borate, tri(n-butyl)ammonium tetrakis(m-tolyl)borate, tri(n-butyl)ammonium tetrakis(2,4-dimethyl)borate, tri(n-butyl)ammonium tetrakis(3,5-dimethylphenyl)borate, tri(n-butyl)ammonium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, tri(n-butyl)ammonium tetrakis(pentafluorophenyl)borate, 15 N,N-dimethylanilinium tetrakis(p-tolyl)borate, N,N-dimethylanilinium tetrakis(m-tolyl)borate, N,N-dimethylanilinium tetrakis(2,4-dimethylphenyl)borate, N,N-dimethylanilinium tetrakis(3,5-dimethylphenyl)borate, N,N-dimethylanilinium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, N,N-dimethylanilinium tetrakis(pentafluorophenyl)borate, triphenylcarbenium tetrakis(p-tolyl)borate, 20 triphenylcarbenium tetrakis(m-tolyl)borate, triphenylcarbenium tetrakis(2,4-dimethylphenyl)borate, triphenylcarbenium tetrakis(3,5-dimethylphenyl)borate, triphenylcarbenium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, triphenylcarbenium tetrakis(pentafluorophenyl)borate, tropylium tetrakis(p-tolyl)borate, tropylium tetrakis(m-tolyl)borate, tropylium tetrakis(2,4-dimethylphenyl)borate, tropylium tetrakis(3,5-dimethylphenyl)borate, tropylium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, tropylium tetrakis(pentafluorophenyl)borate, lithium tetrakis(pentafluorophenyl)borate, lithium tetrakis(phenyl)borate, lithium tetrakis(p-tolyl)borate, lithium tetrakis(m-tolyl)borate, lithium tetrakis(2,4-dimethylphenyl)borate, lithium tetrakis(3,5-dimethylphenyl)borate, lithium tetrafluoroborate, sodium tetrakis(pentafluorophenyl)borate, sodium tetrakis(phenyl) borate, sodium tetrakis(p-tolyl)borate, 25 30

sodium tetrakis(m-tolyl)borate, sodium tetrakis(2,4-dimethylphenyl)borate, sodium tetrakis(3,5-dimethylphenyl)borate, sodium tetrafluoroborate, potassium tetrakis(pentafluorophenyl)borate, potassium tetrakis(phenyl)borate, potassium tetrakis(p-tolyl)borate, potassium tetrakis(m-tolyl)borate, potassium tetrakis(2,4-

5 dimethylphenyl)borate, potassium tetrakis(3,5-dimethylphenyl)borate, potassium tetrafluoroborate, tri(n-butyl)ammonium tetrakis(p-tolyl)aluminate, tri(n-butyl)ammonium tetrakis(m-tolyl)aluminate, tri(n-butyl)ammonium tetrakis(2,4-dimethyl)aluminate, tri(n-butyl)ammonium tetrakis(3,5-dimethylphenyl)aluminate, tri(n-butyl)ammonium tetrakis(pentafluorophenyl)-

10 aluminate, N,N-dimethylanilinium tetrakis(p-tolyl)aluminate, N,N-dimethylanilinium tetrakis(m-tolyl)aluminate, N,N-dimethylanilinium tetrakis(2,4-dimethylphenyl)aluminate, N,N-dimethylanilinium tetrakis(3,5-dimethylphenyl)aluminate, N,N-dimethylanilinium tetrakis (pentafluorophenyl)aluminate, triphenylcarbenium tetrakis(p-tolyl)aluminate, triphenylcarbenium tetrakis(m-

15 tol)aluminate, triphenylcarbenium tetrakis(2,4-dimethylphenyl)aluminate, triphenylcarbenium tetrakis(3,5-dimethylphenyl)aluminate, triphenylcarbenium tetrakis(pentafluorophenyl)aluminate, tropylium tetrakis(p-tolyl)aluminate, tropylium tetrakis(m-tolyl)aluminate, tropylium tetrakis(2,4-dimethylphenyl)aluminate, tropylium tetrakis(3,5-dimethylphenyl)aluminate,

20 tropylium tetrakis(pentafluorophenyl)aluminate, lithium tetrakis(pentafluorophenyl)aluminate, lithium tetrakis(phenyl)aluminate, lithium tetrakis(p-tolyl)aluminate, lithium tetrakis(m-tolyl)aluminate, lithium tetrakis(2,4-dimethylphenyl)aluminate, lithium tetrakis(3,5-dimethylphenyl)aluminate, lithium tetrafluoroaluminate, sodium tetrakis(pentafluorophenyl)aluminate, sodium

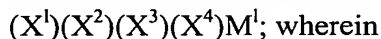
25 tetrakis(phenyl)aluminate, sodium tetrakis(p-tolyl)aluminate, sodium tetrakis(m-tolyl)aluminate, sodium tetrakis(2,4-dimethylphenyl)aluminate, sodium tetrakis(3,5-dimethylphenyl)aluminate, sodium tetrafluoroaluminate, potassium tetrakis(pentafluorophenyl)aluminate, potassium tetrakis(phenyl)aluminate, potassium tetrakis(p-tolyl)aluminate, potassium tetrakis(m-tolyl)aluminate,

30 potassium tetrakis(2,4-dimethylphenyl)aluminate, potassium tetrakis (3,5-

dimethylphenyl)aluminate, potassium tetrafluoroaluminate, or any combination thereof.

20. A catalyst composition comprising:

5 a) a half-sandwich metallocene compound with the following formula:

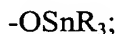


M^1 is selected from titanium, zirconium, or hafnium;

(X^1) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;

10 each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X^1) is independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about
15 20 carbon atoms; a halide; or hydrogen;

(X^2) is selected from a stannoxy group with the following formula:



20 wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

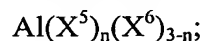
25 (X^3) and (X^4) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about
30 20 carbon atoms; or a halide;

b) a chemically-treated solid oxide comprising a solid oxide treated with an electron-withdrawing anion, wherein

the solid oxide is selected from silica, alumina, silica-alumina, aluminum phosphate, heteropolytungstates, titania, zirconia, magnesia, boria, zinc oxide, mixed oxides thereof, or mixtures thereof; and

the electron-withdrawing anion is selected from fluoride, chloride, bromide, phosphate, triflate, bisulfate, sulfate, or combinations thereof; and

c) an organoaluminum compound with the following formula:



wherein (X^5) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^6) is selected from alkoxide or aryloxy, any one of which having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

21. The catalyst composition of Claim 20, wherein the weight ratio of the organoaluminum compound to chemically-treated solid oxide is from about 5:1 to about 1:1000.

22. The catalyst composition of Claim 20, wherein the weight ratio of the chemically-treated solid oxide to the half-sandwich metallocene compound is from about 10,000:1 to about 1:1.

23. The catalyst composition of Claim 20, wherein:

the solid oxide is selected from silica, alumina, silica-alumina, or mixtures thereof;

the electron-withdrawing anion is selected from fluoride, chloride, bromide, phosphate, triflate, bisulfate, sulfate, or any combination thereof; and

the organoaluminum compound is selected from trimethylaluminum (TMA), triethylaluminum (TEA), tripropylaluminum, diethylaluminum ethoxide, tributylaluminum, diisobutylaluminum hydride, triisobutylaluminum (TIBAL), diethylaluminum chloride, or any combination thereof.

24. The catalyst composition of Claim 20, wherein the half-sandwich metallocene comprises $(\eta^5\text{-C}_5\text{H}_5)\text{Ti}(\text{OSnPh}_3)\text{Cl}_2$, the chemically-treated solid oxide comprises chlorided zinc-alumina, and the organoaluminum compound comprises triisobutylaluminum (TIBAL).

5

25. A process to produce a catalyst composition comprising contacting a half-sandwich metallocene compound and an activator, wherein:

a) the half-sandwich metallocene compound has the following formula:

10 $(\text{X}^1)(\text{X}^2)(\text{X}^3)(\text{X}^4)\text{M}^1$; wherein

M^1 is selected from titanium, zirconium, or hafnium;

(X^1) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;

each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X^1) is independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

20 (X^2) is selected from a stannoxy group with the following formula:



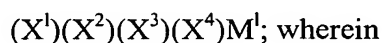
wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

30 (X^3) and (X^4) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic

group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; or a halide; and

- 5 b) the activator is selected from an aluminoxane, an organoboron compound, an ionizing ionic compound, a clay material, a chemically-treated solid oxide combined with an organoaluminum compound, or any combination thereof.

26. A process for polymerizing olefins comprising contacting a catalyst
10 composition with at least one type of olefin monomer, wherein the catalyst composition comprises a half-sandwich metallocene compound with the following formula:



M^1 is selected from titanium, zirconium, or hafnium;

- 15 (X^1) is selected from cyclopentadienyl, indenyl, fluorenyl, substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl;

 each substituent on the substituted cyclopentadienyl, substituted indenyl, or substituted fluorenyl (X^1) is independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an
20 oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

- 25 (X^2) is selected from a stanoxo group with the following formula:



 wherein R is independently selected from alkyl, cycloalkyl, aryl, aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; OR' wherein R' is selected from alkyl, aryl,
30 aralkyl, substituted alkyl, substituted aryl, or substituted aralkyl, any one of which having from 1 to about 20 carbon atoms; F; Cl; Br; or I; and

(X³) and (X⁴) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; or a halide.